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The Champlain Canal as a non-indigenous species corridor

J. Ellen Marsden *, Bret J. Ladago

Rubenstein Ecosystem Science Laboratory, University of Vermont, 3 College St, Burlington, VT 05401, United States

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ABSTRACT

Canals that link previously unconnected drainages remain one of the largely unaddressed vectors of exotic species transfer. Aquatic organisms are generally assumed to pass through canals actively, by passive movement, or mediated by boats; here, we demonstrate that population range extension within canals is also a dispersal mode. Our study was focused on the northern section of the Champlain Canal, which links Lake Champlain (Vermont-New York-Quebec) to the Hudson River. We sampled three dewatered locks in 2008, 2010, and 2011, and the canal channel in 2010 and 2011 using gillnets, minnow traps, electroshocking, hand nets, ichthyoplankton nets, benthic dredge, petit ponar, and hand picking; collections focused on fishes, plants, and molluscs. Secchi disk, dissolved oxygen, and temperature data were collected at the surface and bottom of the canal throughout the sampling period. We collected 43 fish species, one fish hybrid, 29 molluscs, 26 plants, three crayfish species, mudpuppy, and one species of freshwater sponge. Almost half of these species are exotic to one or both of the connected drainages. Among the fishes, evidence of reproduction within the canal was found for over half of the species. Thus, the Champlain Canal is not simply a route for invasions, but is a semi-natural ecosystem with a rich community of self-sustaining species. Canal construction or retro-fitting with barriers that ecologically separate the connected waterways could significantly reduce the threat of aquatic invasions.

Introduction

Ecological and economic impacts of invasive species are becoming more important as global commerce and landscape changes have increased rates of introductions (e.g., Pimentel et al., 2005; Crowl et al., 2008; Ricciardi, 2006). Aquatic invasive species are currently a particular focus of management and research in the Great Lakes and connected waterways as a consequence of the recent invasion by several particularly problematic species, including zebra mussel (*Dreissena polymorpha*), quagga mussel (*Dreissena rostriformis*), spiny water flea (*Bythotrephes longimanus*), and round goby (*Neogobius melanostomus*). Prevention of invasions is vastly less expensive than managing them in perpetuity (Leung et al., 2002); however, recognition of invasion vectors, and finding methods to block them, is necessary. Canals that link previously isolated watersheds represent a vector that is particularly challenging to address, due to conflicts between their use as human pathways (recreational and commercial boat traffic) and use by biological invaders.

Several studies have modeled dispersal probability and rate of aquatic invasions from various vectors (e.g., Leung et al., 2006; Kolar and Lodge, 2001; Johnson et al., 2001), but the potential for invasions via canals have not been empirically evaluated by field sampling. When a canal links previously isolated bodies of water, the canal is often assumed to be the most likely vector of interbasin transfer of species (e.g., Bij de Vaate et al., 2002; Daniels, 2001; Galil et al., 2015; Hulme, 2015; Nunes et al., 2015). However, canals were historically often inhospitable to aquatic life due to poor water quality and periods of dewatering, deoxygenation, and freezing (Daniels, 2001). In recent decades, improvements in canal environments and lock operations have made them much more likely to support aquatic organisms (Daniels, 2001), yet little direct information (i.e., field data) is available on the current invasion pressure from canals, which taxa tend to traverse or be resident in a particular canal (i.e., are plants more abundant that animals? Are benthic invertebrates more diverse than fishes?), abundance of individual species (what is the 'invasion pressure' of different taxa?), and how rapidly species move through the canal (what types of species are likely to use the canal effectively as an invasion pathway?). Data on species already present in a canal could be used to predict taxa that are likely to invade in the future; yet, to date, little targeted sampling has been done in canals to assess resident flora and fauna, or their potential as an non-indigenous species vector.

The Champlain Canal, which links the Hudson River, Great Lakes, and Lake Champlain, offers a useful case to examine the role of canals as non-indigenous species vectors; here, we particularly focus on invasions into Lake Champlain. The canal is relatively short (106 km), and is mostly used for recreational traffic, estimated as 89% of 24,976 cumulative vessel lockages in 2004 (New York State Canal System Annual Traffic Report, 2004). Commercial traffic has declined from 259,597 tonnes in 1988 to 40 in 1997 (New York State Canal

* Corresponding author.
E-mail address: ellen.marsden@uvm.edu (J.E. Marsden).

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Corporation, 1997). The native and non-indigenous species in the linked ecosystems are well documented. Lake Champlain contains 50 non-indigenous species (Marsden and Hauser, 2009; two more species have invaded since 2009), over 180 species are established in the Great Lakes (Mills et al., 1993; Ricciardi, 2006), and over 90 in the Hudson River (Strayer, 2006). Of the 37 species in Lake Champlain for which the vector can be identified with reasonable confidence, 20 (54%) entered the lake via at least one of the two canals connected to Lake Champlain, and most of these used the Champlain Canal (Marsden and Hauser, 2009, unpublished data). Lake Champlain has also likely been a conduit for invasions between the connected systems; Daniels (2001) lists five fish species in the Hudson River that may have used Lake Champlain and the canal to transit from the St. Lawrence River, and eight that invaded the St. Lawrence River in the reverse direction. There is a high probability that additional invasions will occur. Most other pathways of invasion into Lake Champlain have been at least partially addressed, including bait bucket introductions, deliberate fish stocking, and horticulture escapes (Marsden and Hauser, 2009). The canal remains the major uncontrolled vector for non-indigenous species introductions into Lake Champlain, and also from Lake Champlain into the connected water bodies. Round goby, quagga mussel, and Piedmont elimia snail (*Elimia virginica*) have already been seen in the New York State canal system (USGS, 2016); but, because there is no regular or systematic sampling in the canal, changes in species distributions are only sporadically documented.

Development of a biological barrier on the Champlain Canal has been discussed since 2008, when the Asian clam, *Corbicula fluminea*, was discovered on the south side of lock 8 at Fort Edwards (U.S. Geological Survey, 2008, Marsden and Hauser, 2009). Optimal design of a biological barrier on the canal requires information about the types of species that are most likely to use the canal as a corridor between connected basins. The purpose of this study was to sample species present in the Champlain Canal to identify the types of species that may use the canal as a corridor, and which vectors (active movement or passive transport) may be likely to move species. Detection of any species in the canal that are not currently found in one of the connected bodies of water (Lake Champlain or the Hudson River) would also provide a baseline from which to track future movements of these species.

Methods

Site description

The Champlain Canal, opened in 1823, is entirely within New York state and extends 97 km from Whitehall southward to Waterford (Fig. 1). During its initial construction and subsequent modifications, the canal channel incorporated, in part, existing natural channels and waterways. Between lock 1 at Waterford and lock 7 at Fort Edward, the canal is mostly contained within the Hudson River channel and from this point forward we refer to this section the Hudson River corridor. A 4-km section of constructed canal parallels the Hudson River north of lock 6 at Fort Miller, NY. North of lock 7, the canal leaves the Hudson corridor and is a dug channel. The canal passes over a height of land between lock 8 at Fort Edward and lock 9 at Fort Ann, so that water drains toward the Hudson River south of lock 8, and toward

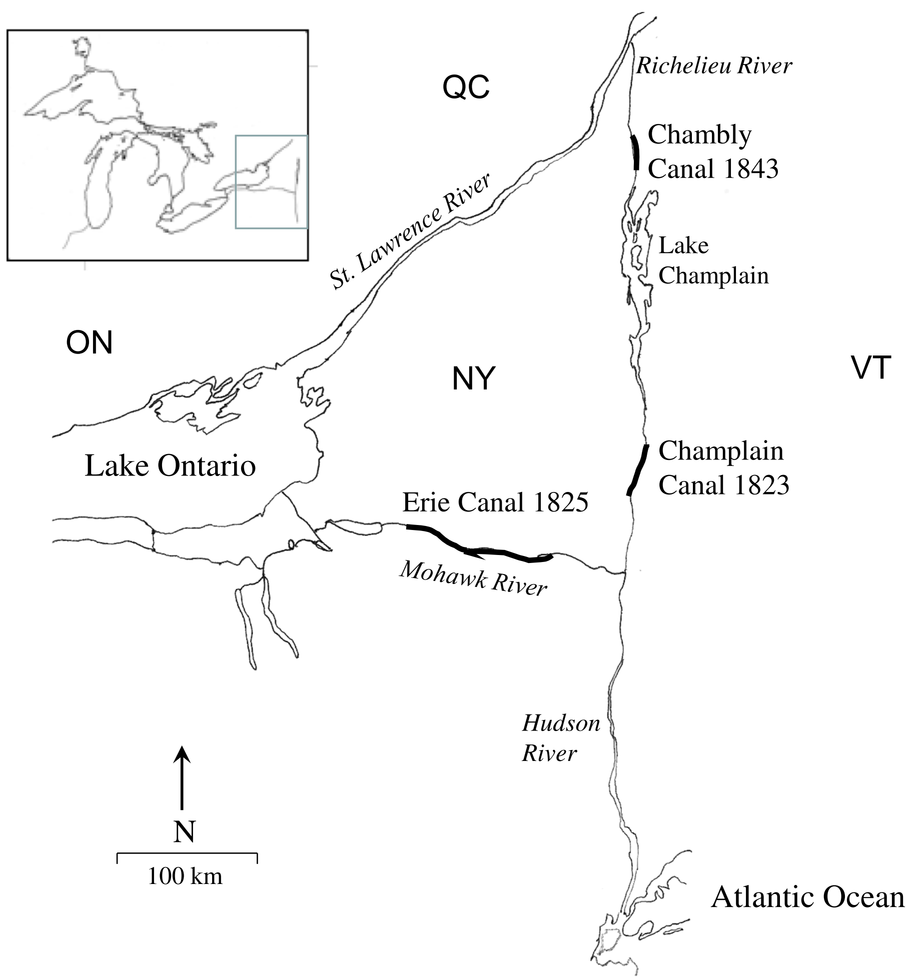

Fig. 1. Canals connecting the Hudson River with the Great Lakes and the St. Lawrence River.

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